

Problem Solving Agents

Sensible Agents

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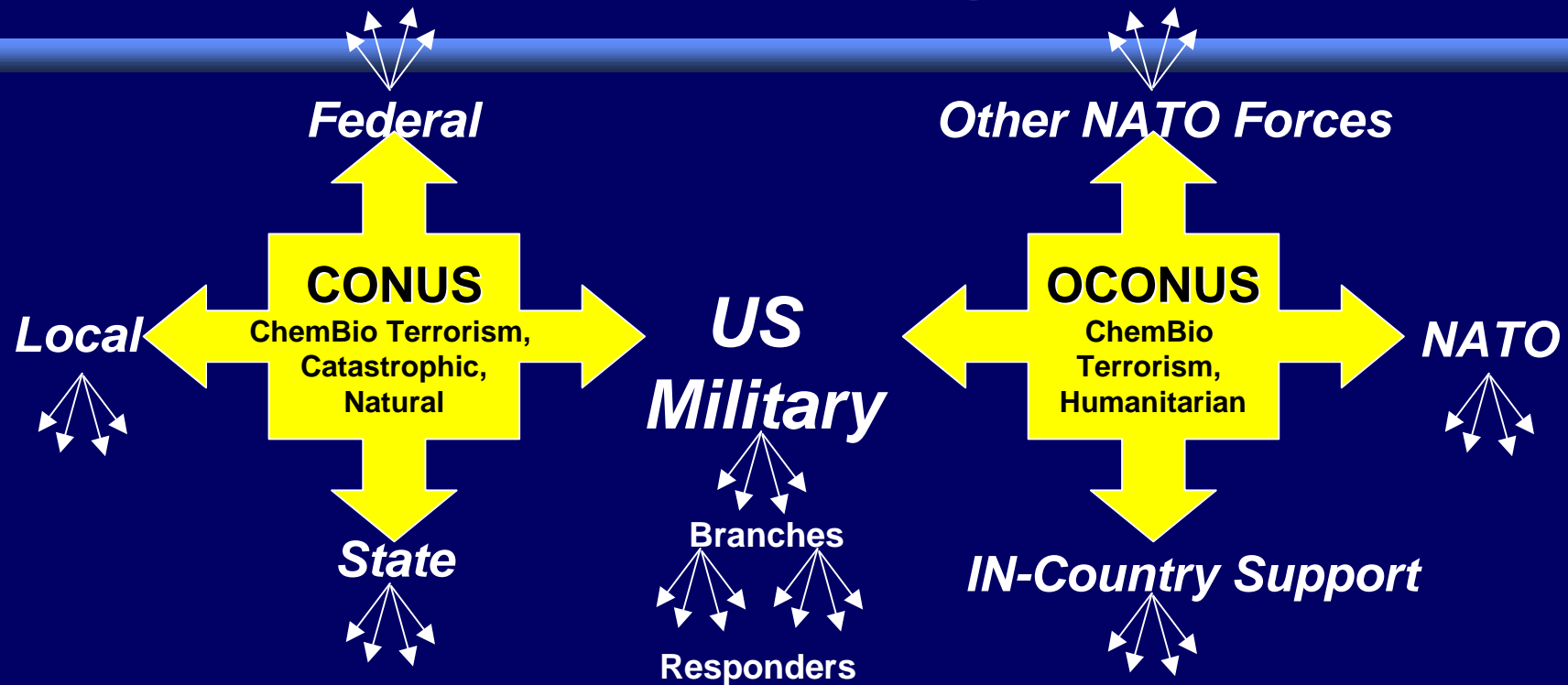
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Example Challenge Problem



Different Mission Types – Humanitarian, CONUS terrorism, OCONUS terrorism

Different CONOPS – mission goals, treatment protocol, reporting protocol, data acquisition protocols



What makes a Good Problem-Solver/ Decision-Maker?

Understand the problem and problem constraints

The Problem (Goal): What's the Mission? Strategic Goals? Tactical Goals?

The Situation Constraints: Deadlines, Priorities, Quality of Solution, Environmental Conditions

Knowledge Required to Solve Problem

Knowing what decisions/actions to take

Knowing what resources are required

What do I know about
solving the problem?

What do potential
"Team Members" know
About Solving problem?

What do enemies
Or Competitors know
About solving problem?

Assessing Resource Capacity to Plan and Execute a Solution

Availability and Accessibility to resources

Completeness and Certainty of knowledge about resources

Resources = Data/Information, Time, Communication, Domain-specific resources (weapons)

What are MY resources?

Resources of potential
"Team Members"?

Resources of
Enemies or Competitors?

THEN -- What is the Most Appropriate Organization to Solve the Problem??



Objective



**Mission Driven, Situation-based Coordinated CONOPS Promoted by
Equipping Every Decision-Making Node with a
Sensible Agent to Determine Best Problem-Solving Organization**



**Solve problem
(mission goals,
strategic and tactical
plans) alone?**



**Form an
organization to
delegate
parts of problem?**



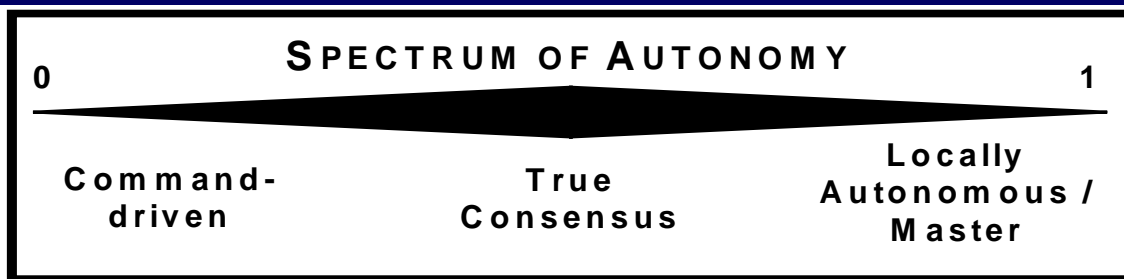
**As part of a problem
solving organization,
what role does each
involved Node play?**



**In these roles,
coordinate plans
and execution**

“Best” Organization? Point on Autonomy Spectrum?

For EVERY Problem (Goal)



➤ Command-driven -- Agent does not make decisions; must obey orders given by Master agent.

➤ True Consensus – Each Agent is a team member, sharing decision-making tasks with other agents.

➤ Locally Autonomous / Master -- Agent plans alone; may or may not give orders to other agents.

Autonomy Representation (G, D, C)

- Focus: **G = the GOAL/Problem**
- Decision-Makers: **D = (Agent(s), Strength)**
 - **WHICH AGENTS make decisions**
 - **THEIR RELATIVE STRENGTH** in the decision-making process
- Authority Constraint: **C = (Agents) bound to execute decisions**

Locally Autonomous (LA)

Focus (G) = { MyGoal }
Decision-Makers (D) = { Me }
Authority-Over Constraints (C) = { Me }

Command-Driven (CD)

Focus (G) = { MyGoal }
Decision-Makers (D) = { You }
Authority-Over Constraints (C) = { Me }

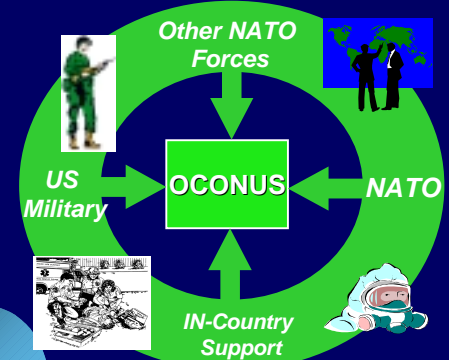
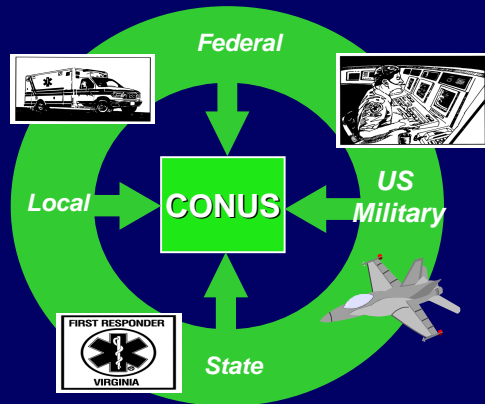
Consensus (CN)

Focus (G) = { MyGoal, YourGoal }
Decision-Makers (D) = { Me, You }
Authority-Over Constraints (C) = { Me, You }



Dynamic Adaptive Autonomy

Is the SAME Organization (Autonomy Level) OPTIMAL for a GIVEN PROBLEM/GOAL for ALL TIME?



Comm
Bandwidth?

Deadlines?
Time?

How much do I
know about HOW
to Solve Problem?

Goal Priorities?
Solution
Quality?

What is my
Resource
Capacity to Solve
Problem?

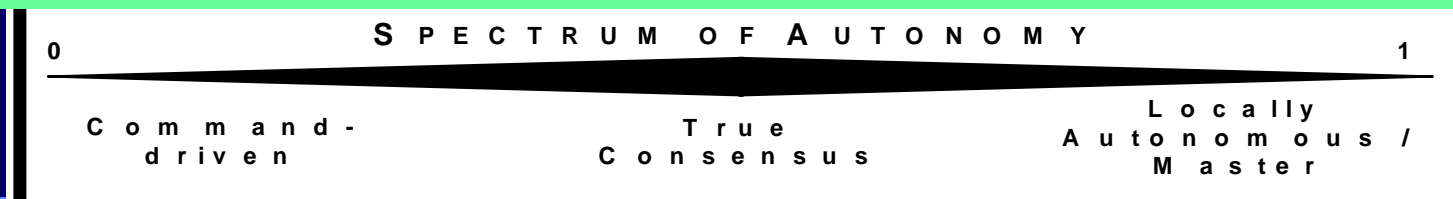
For Intel, Assets,
Weapons, etc.
• Availability and
Accessibility
• Completeness
and Certainty

Knowledge &
Resources of
Others?

Others Willing to
Work with ME
and/or plan for
ME?

Trust in Others?

Dynamic Adaptive Autonomy = Situation-based Selection of Operational Point Along Spectrum



Experimental Results

Barber, Goel and Martin, "The Motivation for Dynamic Adaptive Autonomy in Agent-Based Systems." Proceedings of the 1st Asia-Pacific Conference on Intelligent Agent Technology (IAT '99), pg. 131-140 (Won Award for Best Paper). December 14-17, 1999, Hong Kong.

Measure	Comm Status	Level of Difficulty			
		0-10	10-25	25-40	40-50
TTS	EXIST	MC	MC/LA	--	--
	N/E	LA	LA	--	--
LOI	EXIST	--	CN	LA	MC
	N/E	--	MC	MC	MC/LA
# of Freqs Attempted	EXIST	LA/MC	MC/LA	LA	LA/MC
	N/E	CN	CN	CN	CN
# of Messages	EXIST	LA	LA/MC	LA	LA
	N/E	N/A	N/A	N/A	N/A

Performance Measures

(TTS) Time to Solution -- Interference Free State

(LOI) Average Level of Interference Over Problem-Solving Time

of Frequencies Attempted

of Messages Passed



Sensible Agent Architecture



Local
U.S.'s
Goals

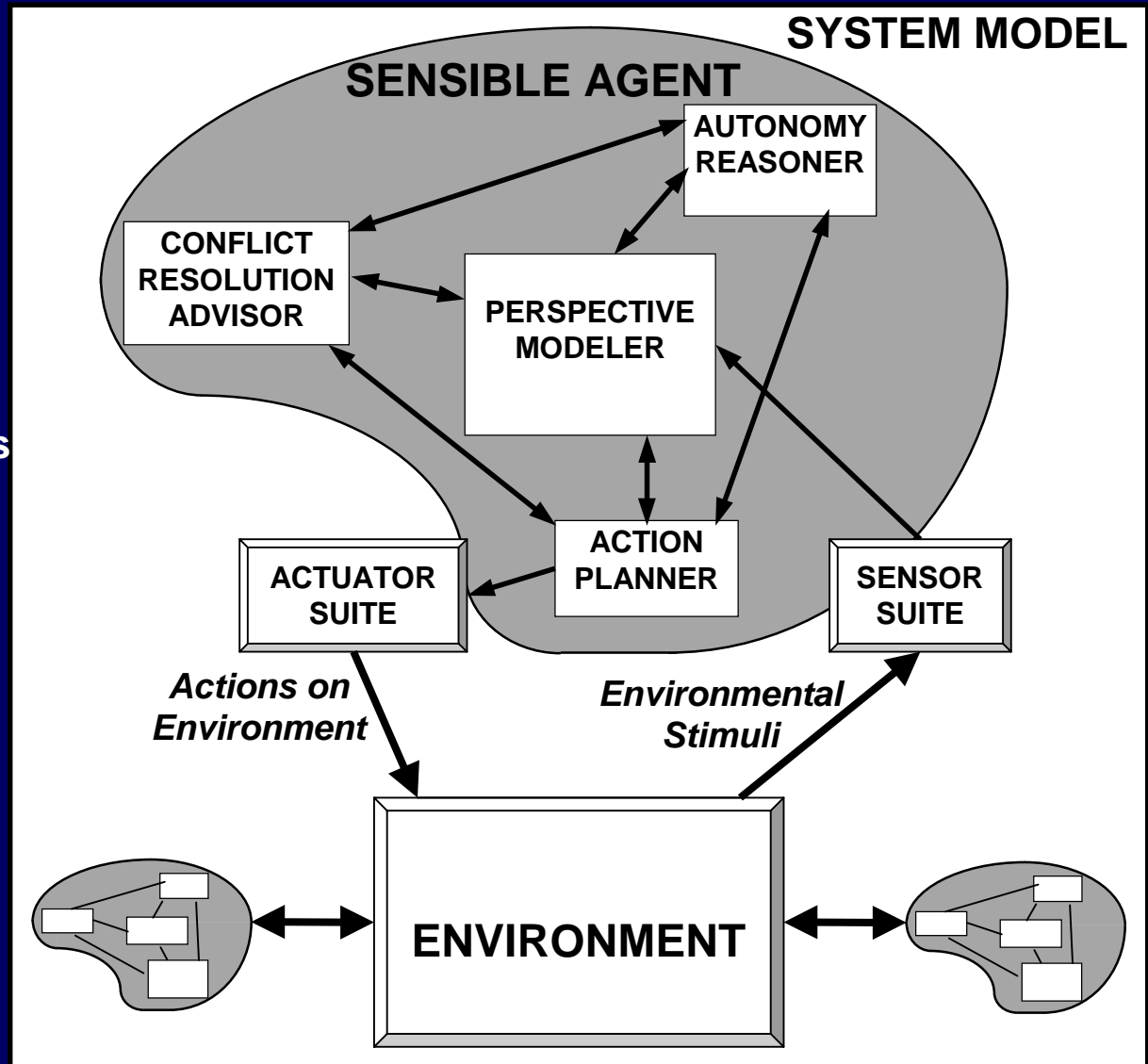
System
NATO's
Goals

Sensible Agent:

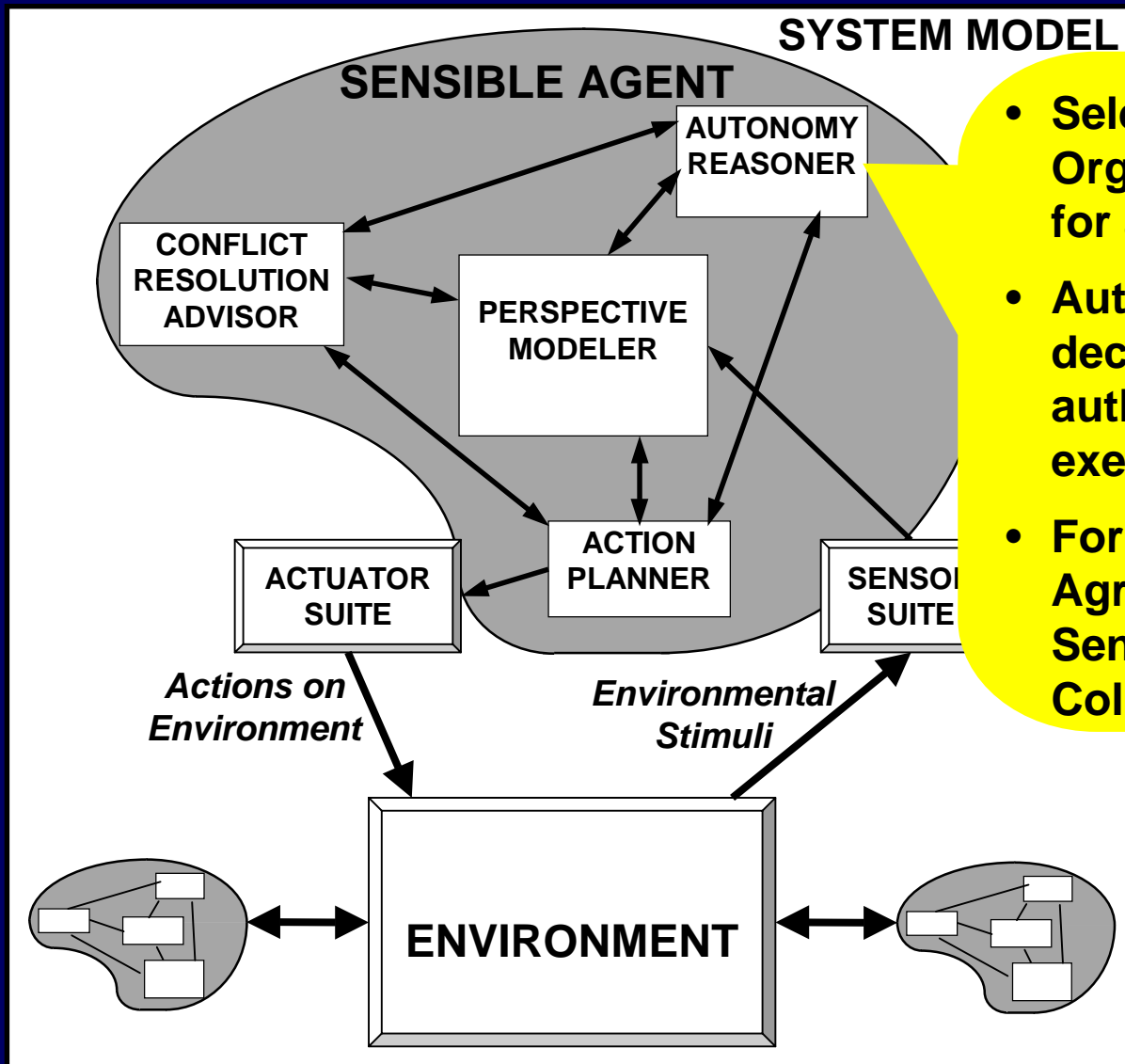
- Agent understands system goals and local goals (and trade-offs)
- Select “Best” Organization to Plan and Execute to Achieve Goals

Hypothesis:

The operational level of agent autonomy is key to an agent's ability to respond to situation context, conflicting goals, and constraints on plans and execution

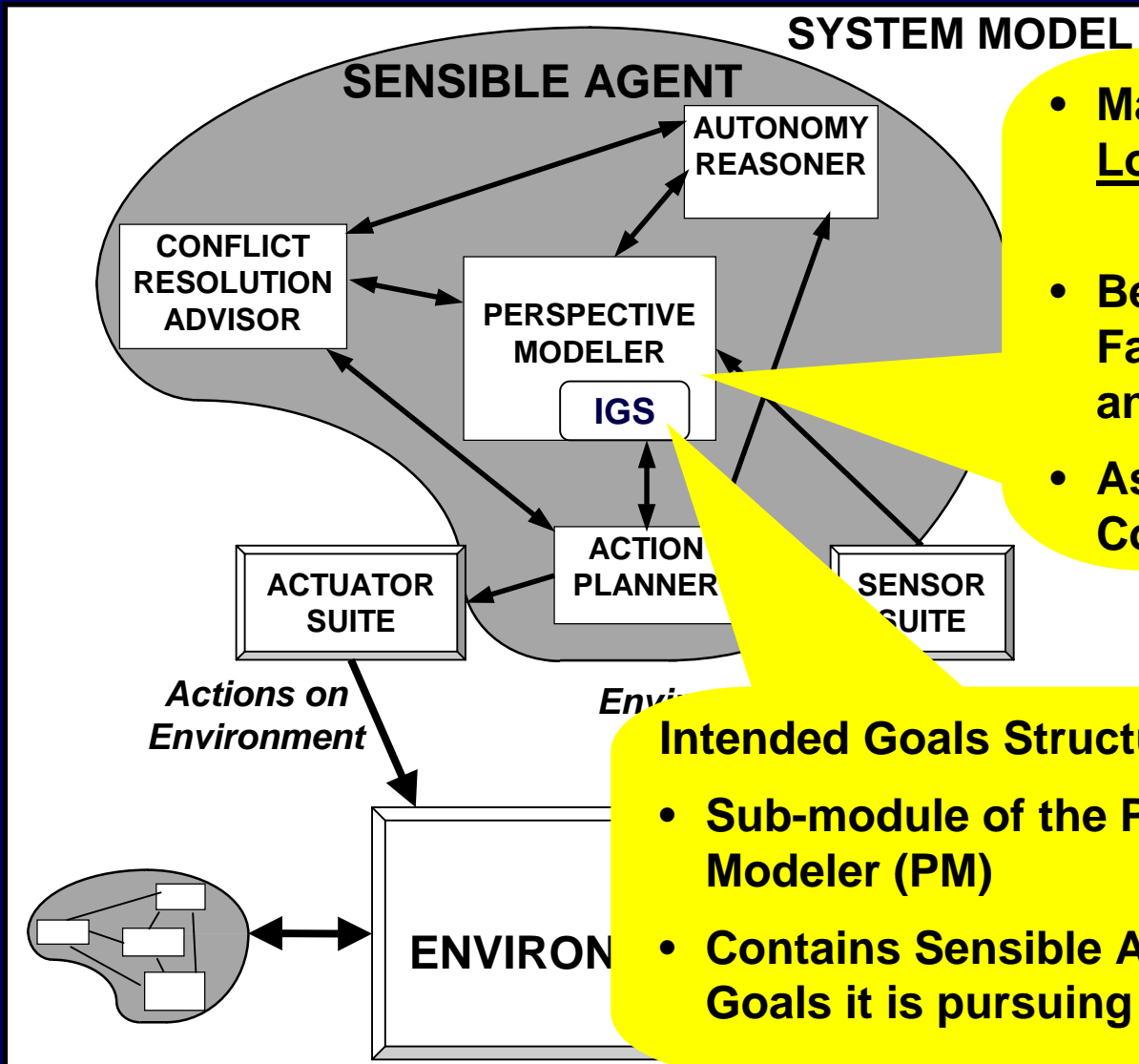


Autonomy Reasoner (AR)



- **Selects Appropriate Organization (Autonomy Level) for a goal to be achieved**
- **Autonomy Level dictates decision-making control and authority structure for execution**
- **Forms Agent Interaction Agreements with Other Sensible Agents for Collaborative Problem Solving**

Perspective Modeler (PM)

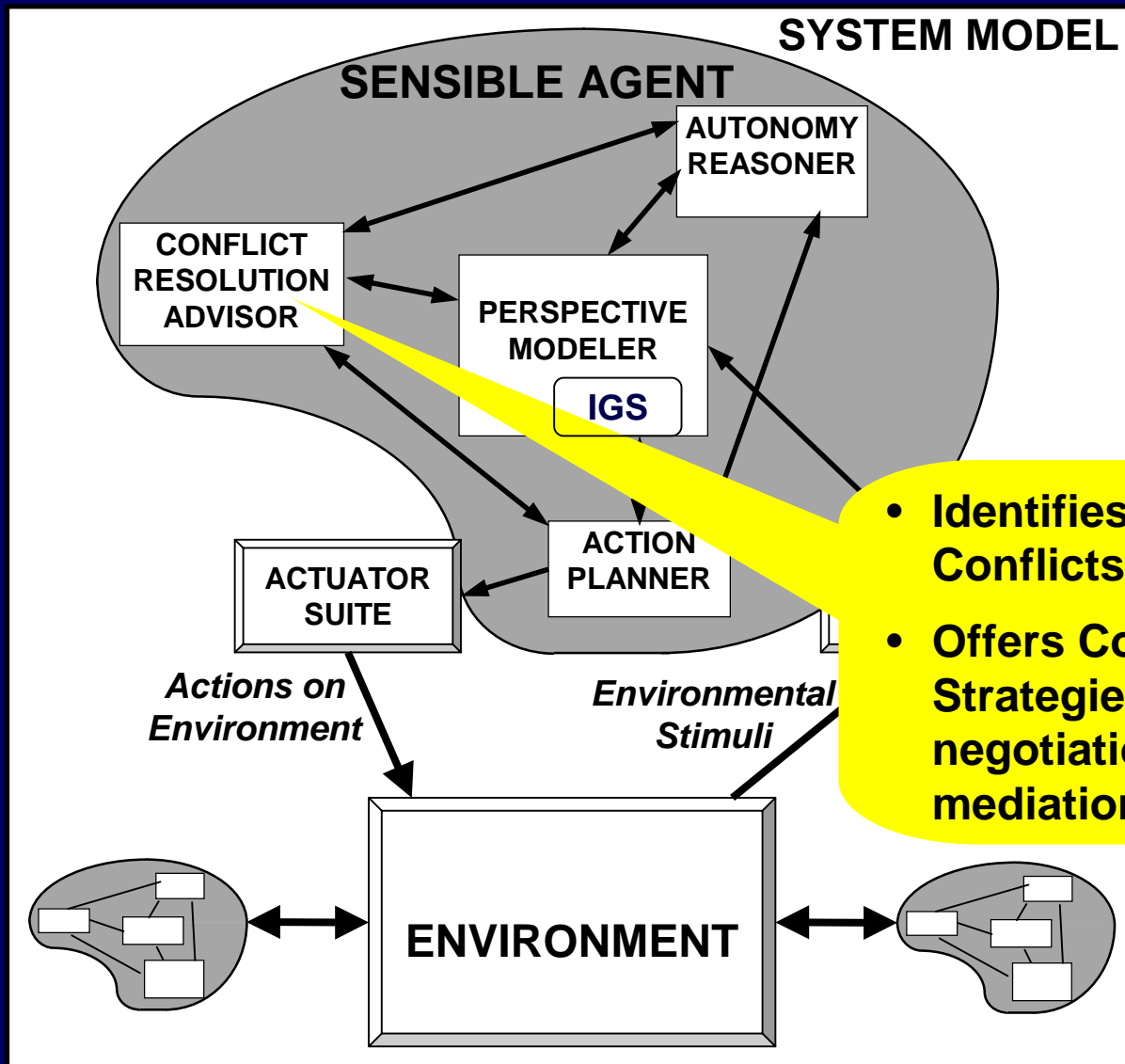


- Maintains Sensible Agent's Local, Subjective Beliefs
- Beliefs = Understanding of Facts and State of Itself, Others, and the Environment
- Assess Information Completeness and Uncertainty

Intended Goals Structure (IGS) --

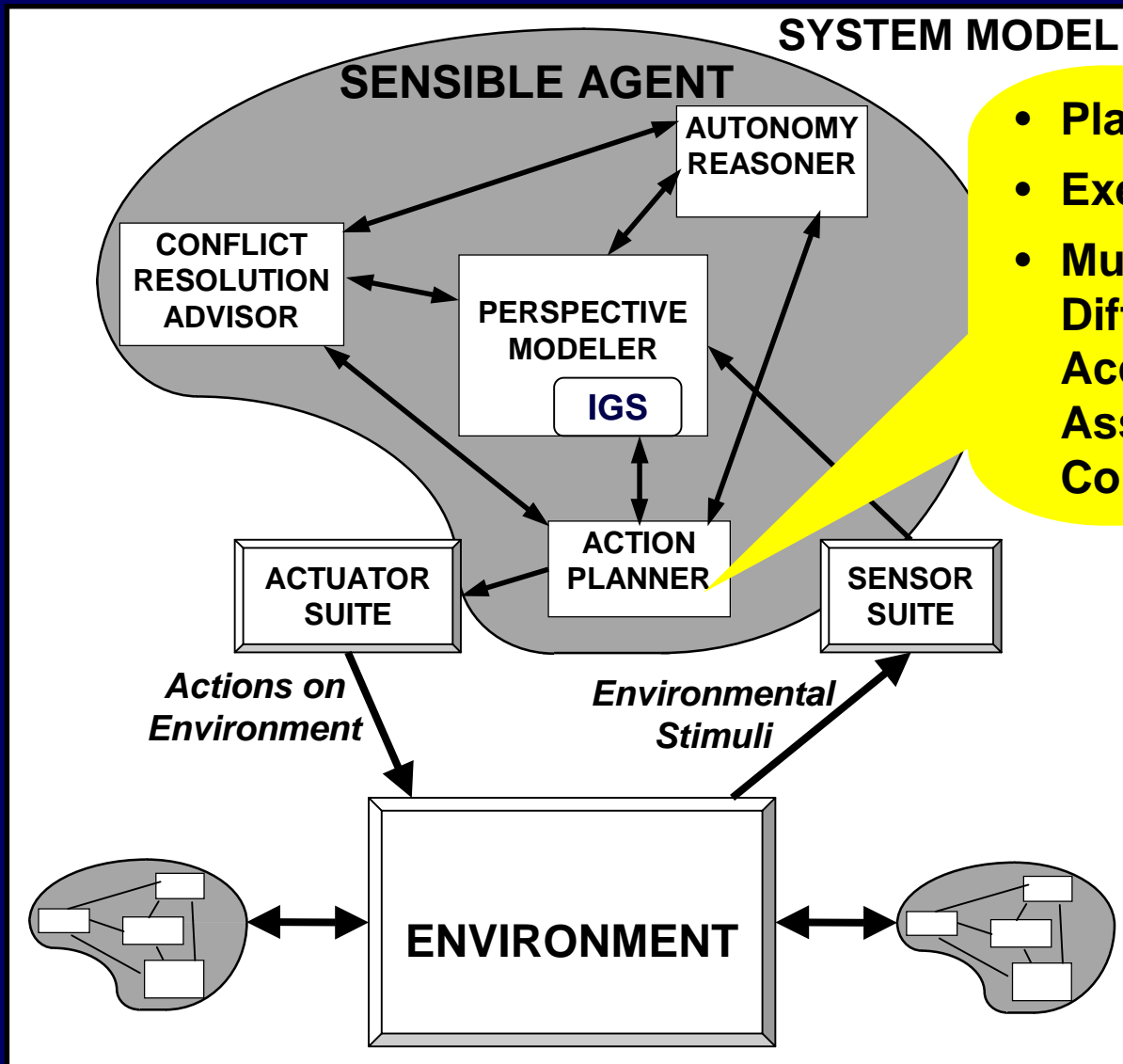
- Sub-module of the Perspective Modeler (PM)
- Contains Sensible Agent's Goals it is pursuing

Conflict Resolution Advisor (CRA)



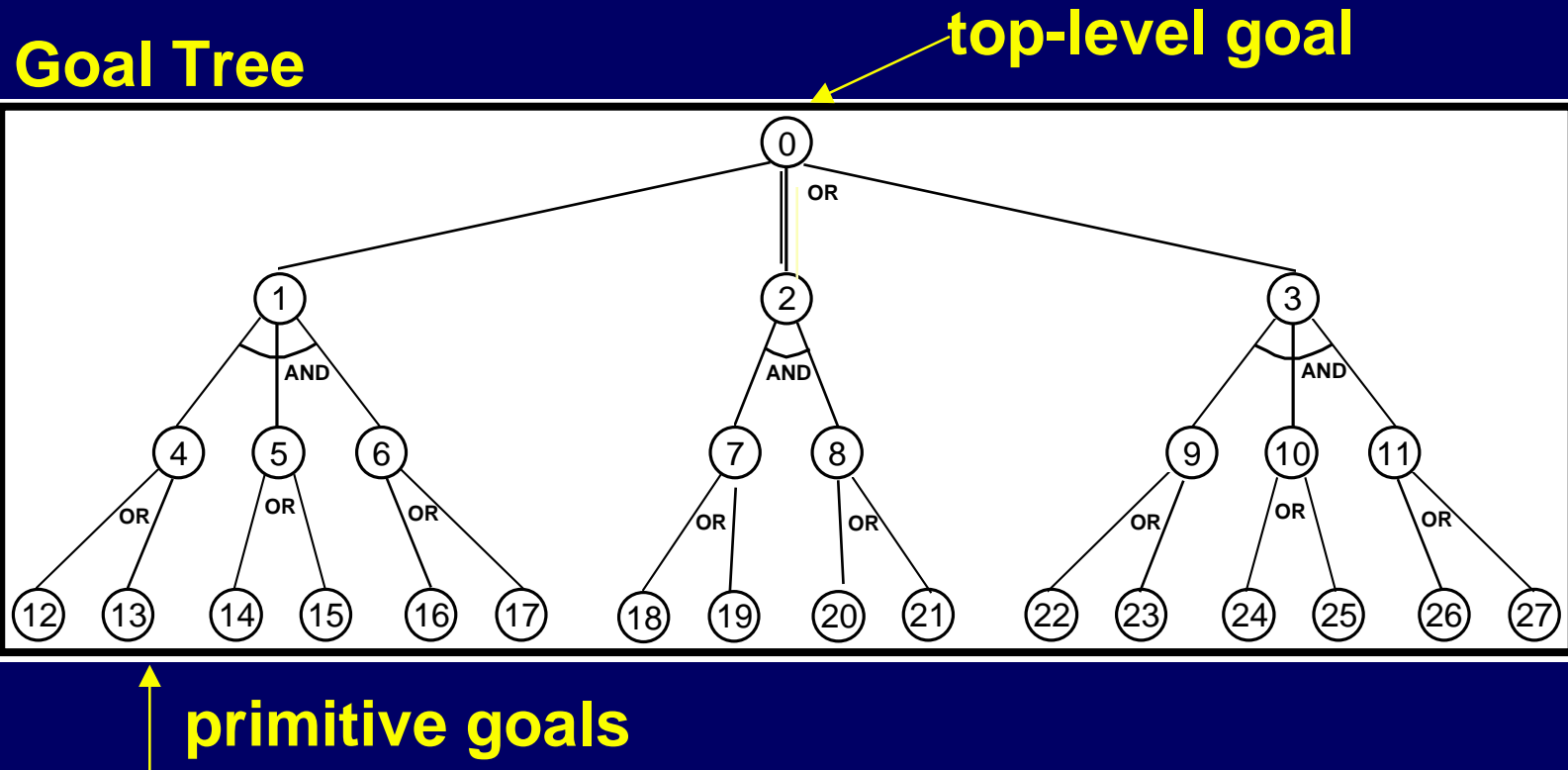
- Identifies and Classifies Conflicts (Goal, Belief, Plan)
- Offers Conflict Resolution Strategies (e.g. voting, negotiation, arbitration, mediation) to Action Planner

Action Planner



- Plans to Solve Problems/Goals
- Executes Plans
- Must be Capable of Using Different “Strategies” According to Autonomy Assignments and Types of Conflicts Detected by CRA

Representing the Agent's Solution Options to Solve Problem

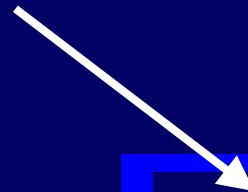


Each candidate goal has some
inherent utility: $(U_{\text{system}}, U_{\text{agent}})$



Application of Autonomy Assignments

The Agent Starts With One or More Initial Intended Goals (Goals It Has Committed to Pursue)



Application of Autonomy Assignments

**As Each Intended Goal
Appears in the IGS, the AR
Applies an Autonomy
Assignment to that Goal**

**Autonomy
Reasoner
(AR)**

Locally Autonomous (LA)

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**Perspective
Modeler
(PM)**

**Intended Goal
Structure (IGS)**



Application of Autonomy Assignments

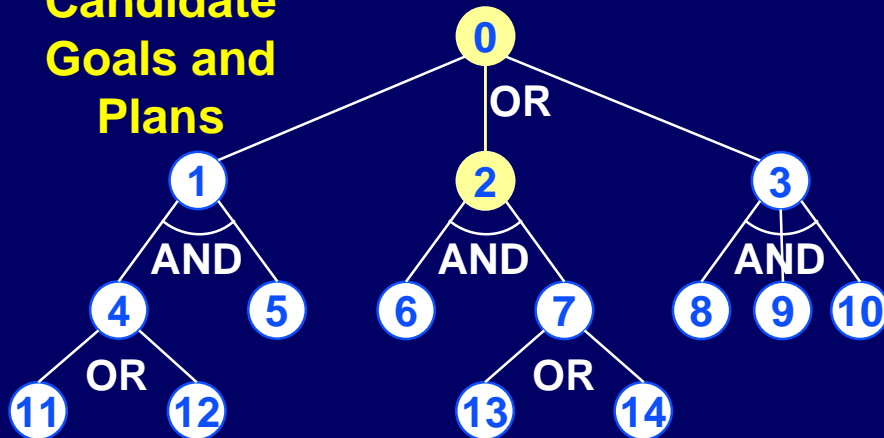
Action Planner (AP)



The AP Selects From Alternatives and Inserts into IGS.

AP Selects and Allocates Among Agents (Itself or Others)

Candidate Goals and Plans



Perspective Modeler (PM)

Intended Goal Structure (IGS)



Application of Autonomy Assignments

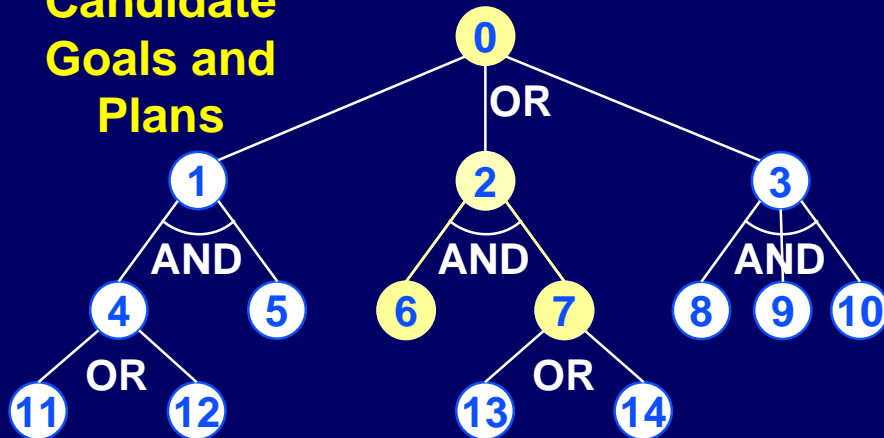
Action Planner (AP)



Autonomy Reasoner (AR)

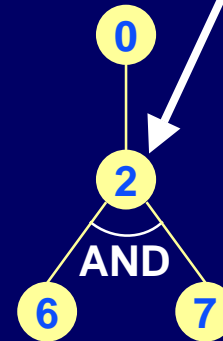
Consensus (CN)

Candidate Goals and Plans

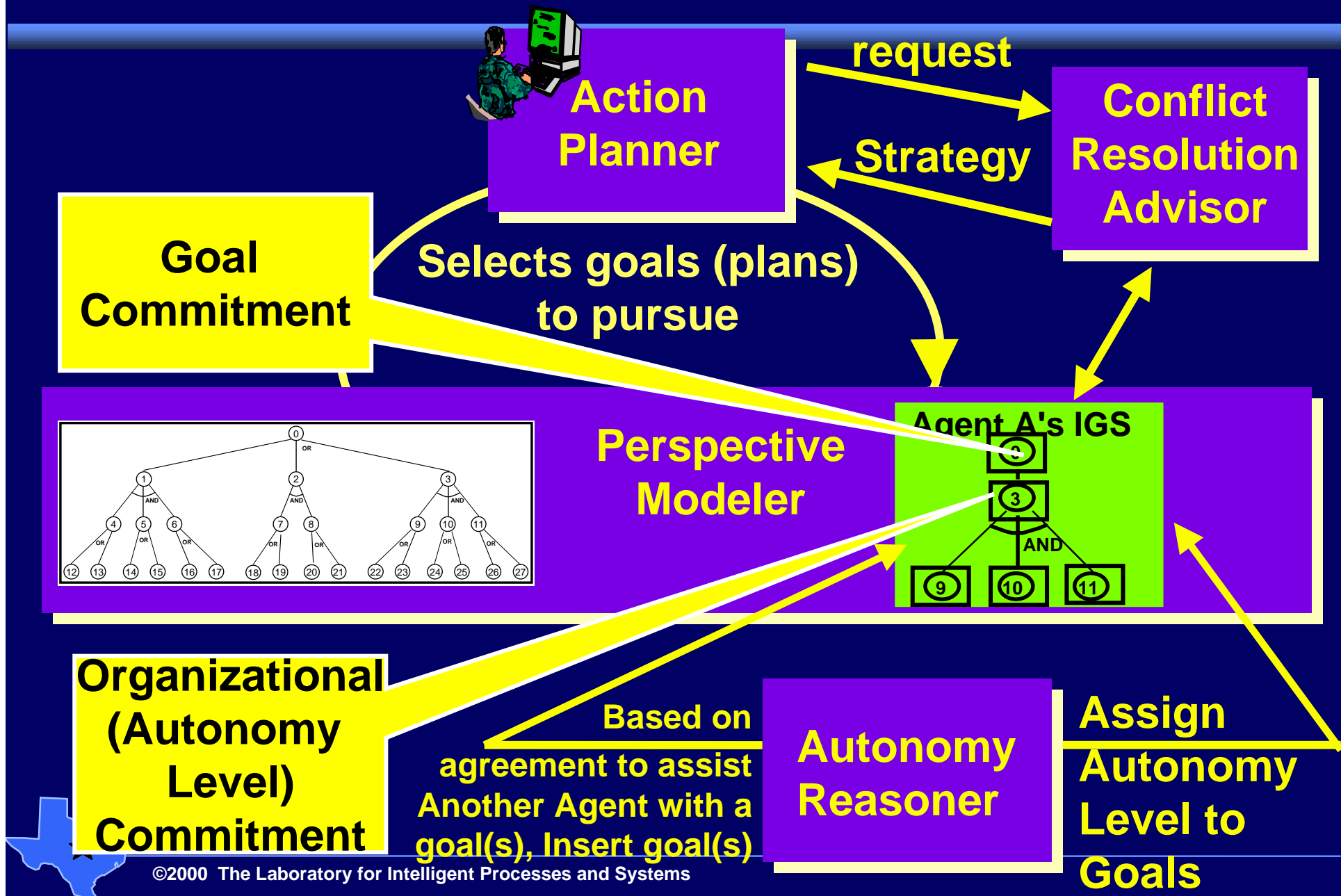


Perspective Modeler (PM)

Intended Goal Structure (IGS)



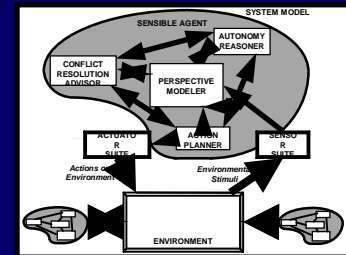
Sensible Agent Module Interaction



Summary

➤ **Sensible Agent Dynamic Adaptive Autonomy delivers the “best” problem solving organization based on the situation:**

- knowledge certainty and information completeness about other agents (benevolent, non-benevolent, or threat) and environment,
- communication constraints,
- domain-specific resource accessibility,
- goal deadlines and goal priorities and
- goal, plan, or belief conflicts



➤ **Formally specified Testbed implementation for**

- Parallel development
- Rapid Integration, Rapid Prototyping
- Repeatable Experimentation
- Visualization of Operation
- Accessibility by 3rd Parties

